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AUTHOR	Tytler, Russell; Sharpley, Brian; Tsiastias, Sophie
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ABSTRACT

Is the way being lost in teaching science? Many primary schools do not have a well developed culture of science teaching and learning, there is a declining interest in science over the years 7 to 10, and there are proportionally fewer students continuing onto science in the senior years. In response to these concerns, the Victorian Department of Education, Employment and Training (DEET) established a major initiative, the Science in Schools (SiS) Research Project, to enhance and invigorate science teaching and learning. During 2000 and 2001 the project team has worked with teachers in primary and secondary schools across Victoria to introduce new initiatives into their science programs. Central to the project are the SiS Components, a framework that describes effective science teaching, and the SiS Strategy, a process by which schools implement change. This paper outlines the SiS Components and Strategy and describes some of the findings that have emerged from the project. (Contains 25 references.) (MM)

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by
Russell Tytler
Brian Sharpley
Sophie Tsiastias

R. Tytler

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Effective Science Teaching and a Strategy for its Implementation

Russell Tytler, Brian Sharpley, Sophie Tsiastas

Deakin University

Abstract

Are we losing our way in teaching science? We know that many primary schools do not have a well-developed culture of science teaching and learning, there is a declining interest in science over the years 7 to 10, and there are proportionally fewer students continuing onto science in the senior years. In response to these concerns, the Victorian Department of Education, Employment and Training (DEET) established a major initiative, the Science in Schools Research Project, to enhance and invigorate science teaching and learning. During 2000 and 2001 the project team has worked with teachers in primary and secondary schools across Victoria to introduce new initiatives into their science programs. Central to the project are the SiS Components, a framework that describes effective science teaching, and the SiS Strategy, a process by which schools implement change. This paper outlines the Science in Schools (SiS) Components and Strategy and describes some of the findings that have emerged from the project.

Introduction

The Science in Schools Research Project is the largest school science initiative of its kind in Australia for decades. The Project is a major constituent of the Science in Schools initiatives developed by the Victorian Department of Education, Employment and Training (DEET. The purpose of the Science in Schools (SiS) Research Project is to develop and trial a model for improving science teaching and learning in Victorian schools. The SiS Research Project is funded by DEET and run by a consortium managed by the Consultancy and Development Unit (CDU) in the Faculty of Education, Deakin University. The project team operates out of the Deakin Melbourne campus.

The project is currently working with 126 Victorian primary and secondary schools, supporting them to improve their science teaching and learning. In each school involved in the project, a 'SiS Coordinator' (larger schools support more than one coordinator) is provided with time release to plan, to work with teachers in developing ideas and materials or in classrooms, to manage the change process, and to work with the Project Team to implement a testing and monitoring program. Each school has access to CRT funds to provide teachers of science with time release to plan, monitor and refine strategies, and to participate in professional development. The SiS Coordinator in each school is supported by a Consultant who visits regularly, provides input on a negotiated basis, and is in regular email contact.

In Phase 1 of the project, during 2000, we worked with 27 schools to develop, refine and test our model — the **School Improvement Model** — which consists of two major features:

- **The SiS Components**, a framework for describing effective science teaching and learning; and
- **The SiS Strategy**, which is the process by which schools can improve their science teaching and learning.

The Model allows flexibility for schools and teachers to plan and implement initiatives based on the particular needs of the school, within an overall framework provided by the SiS Components.

A Project website (**www.scienceinschools.org**) describes the core features of the Project, acts as an archive for project documents, and contains many examples of science teaching and learning practices that have been developed by the SiS schools, to illustrate the SiS Components.

The Project has a major research component. During 2000, the components were used to develop a mapping procedure to build up a picture and to chart changes in teacher classroom practice. Tests of student learning outcomes, attitudes and perceptions were used to monitor progress and outcomes, and this monitoring is continuing into 2001. We have also collected a substantial amount of qualitative data which has provided insights into how the project has progressed in schools, the processes of teacher and school change and factors which affect this, and many stories of science initiatives.

This paper will focus on the SiS Components; how they were developed, how they drive the project, and the SiS Strategy by which schools work to improve their science teaching and learning. It will also describe the different initiatives and foci for secondary and primary schools.

Describing effective science classroom practice: the SiS Components

It was important, at the outset of the project, to identify what we understood as "effective" teaching and learning in science, that would guide teachers and schools in improving their practice. This is the origin of the SiS Components. The components were developed at the beginning of the project to represent a core 'vision' that drives teaching and learning practice. They continue to be refined and interpreted through their use in practice.

There have been many approaches to the definition of effective science teaching and learning that are described in the literature. None of this work, however, provides a framework that is sufficiently explicit, and contains the necessary breadth, to support a large change project with the complex concerns we were faced with. The starting point for our development of the components was, however, our knowledge of previous work, which has been of a range of types:

- Studies of school programs and questionnaires regarding classroom practice have been used in the US (eg. Yager & Penick 1984, Penick & Yager 1986, Brunkhorst 1992), but these tend to have focused on the very top, 'exemplary' programs and teachers and produce only broad descriptions of their characteristics, such as a greater number and wider range of activities.
- Direct studies of actual 'exemplary' classrooms provide valuable data (Tobin & Fraser 1998, 1990). These can tend to focus on classroom management principles, although in some cases quite sharp insights are generated, as with Treagust's (1991) comparison of two exemplary biology teachers with very different styles.
- Yet another approach has been to develop questionnaire instruments for students, to assess classroom environments (Fraser 1998) and these have been used for instance to identify broad teacher interpersonal characteristics associated with improved student outcomes and attitudes (Wubbels & Brekelman 1998).
- Another approach, seen particularly in the development of science teaching standards (eg. NSES 2000; National Science Standards Committee, ASTA, 2000) is to develop descriptors of effective teaching by workshopping ideas with leading science education professionals. This approach became one part of our own development of the SiS Components.
- In recent years there has been considerable research done into the nature of student learning in science, and students' conceptions. This has led to the development of constructivist / conceptual change teaching approaches which have gained broad

acceptance in the literature as being effective (Wandersee, Mintzes & Novak, 1994; Duit & Treagust, 1998). The PEEL project (Baird & Mitchell, 1986; Baird & Northfield, 1992; Mitchell, 2000), highlighting the importance of metacognition in learning, arose out of this literature. This substantial literature has a lot to say about effective teaching and learning, although its focus tends to be on the conceptual, rather than attitudinal or broader cultural aspects of teaching and learning.

- In Victoria as elsewhere there has been considerable concern about the declining interest in science across the middle years of schooling. The strategies developed to counteract this, for instance in the Victorian Middle Years Research And Development (MYRAD) project, focus on student engagement and autonomy, higher order thinking and learning, and relevance. These principles have also influenced the way the SiS Components have been developed.

Starting with this background work, we set about developing a framework to describe effective teaching and learning in science, that would represent the core project innovation. We believe the value of the resulting SiS Components lies in the breadth of the vision of effective teaching and learning they offer, and their explicitness concerning practice. The stages in development of these components were:

- Preliminary categories describing quality school science practice were developed in a series of informal workshops within the project team, drawing on our previous classroom and school evaluation projects, and our knowledge of the literature;
- These were used as the basis for a telephone (in some cases face to face) interview schedule to explore the practice of teachers and schools with a reputation for effective science teaching. These were selected using a combination of school science performance on statewide tests, and peer reputation using informal networks;
- Initially 12 (and ultimately more than 20, including interstate) teachers were interviewed, and the data analysed to identify key components which seemed to stand out in all or most cases. This process involved a range of team meetings, as well as a reference group of science educators; and
- The components have been further refined and validated by teacher response within the project and their capacity to encourage, support and interpret initiatives, and by an analysis of a substantial body of research and development literature concerning effective science teaching and learning (Tytler & Waldrip, 2001).

The eight SiS components are:

1. The learning environment encourages active engagement with ideas and evidence;

1.1 Students are encouraged and supported to express their ideas, question evidence, and raise issues

1.2 Student input (questions, ideas and expressions of interest) influences the course of lessons.

1.3 Students are encouraged and supported to take responsibility for the purpose, design and analysis of science investigations

2. Students are challenged to develop meaningful understandings;

2.1 Students are challenged to develop deeper level understanding of major science ideas

2.2 Teaching sequences are structured to encourage students to connect and extend ideas across time

2.3 Students are challenged to develop higher order and divergent thinking to respond to science questions

3. Science is linked with students' lives and interests;

Students' interests and concerns (hobbies, media) are reflected in the learning context, and are regularly canvassed in class and linked to science ideas

4. Students' individual learning needs and preferences are catered for;

The teacher monitors and responds strategically to students' varying abilities, learning needs and preferences.

5. Assessment is embedded within the science learning strategy;

5.1 Strategies are used to continuously diagnose and monitor student understandings and perceptions, prior to and during a unit of work.

5.2 A range of styles of assessment tasks is used to reflect different aspects of science and types of understanding

6. Science is represented in its many facets;

The science teaching and learning program represents the different facets of science;

6.1 Investigative processes of science;

6.2 Science and social and personal issues; and

6.3 Science, industry, and science-related professions.

7. The classroom is linked with the broader community;

Science activities link beyond the classroom, by way of projects in the local environment, special projects involving the school community or the wider community, or science competitions and special events.

8. Learning technologies are exploited for their learning potentialities.

8.1 Information and Communication Technologies (ICT) are used strategically to encourage quality learning behaviours and increase students' control over their learning

8.2 A variety of learning technologies are used in a manner that reflects their use by professional scientists

In project documents the components are supported with examples gleaned from the interviews or elsewhere, and also descriptions of practice that are contrary to each component. These have proved essential in establishing a shared understanding of the vision of science teaching and learning underpinning the project.

The SiS Components have been used to develop descriptors of classrooms operating at four different levels on each component, which we are using as a tool for teachers to analyse and reflect on their practice. These are in essence 'Innovation configuration maps' (Hall & Hord, 2001). Each teacher is given a questionnaire based on the component maps, exploring their practice in science. They are then interviewed by the SiS coordinator, and out of the interview an agreed position on each component is reached, as well as a discussion on where the teacher would like to be on each component, at the end of the project.

The component mapping process performs two major functions within the project. Firstly, it is an important aspect of the SiS Strategy in that the questionnaire and interview lay out clearly the nature of the components and establish an early dialogue, and the beginnings of a common language, between the coordinator and individual teachers. Coordinators, reporting on the project, saw the component mapping as having the following effects:

- Evaluating teachers' current practice — "identifying teacher strengths and areas that they would like to improve on";
- Providing ideas and a clear direction and a focus for discussions leading to the school action plans — "the SiS components and mapping tools provided clear direction and wonderful ideas";
- Encouraging a more thoughtful approach to teaching and learning, and raising teacher awareness of the basis of the project. The mapping "allowed teachers to identify and be open about their limitations and expertise"; and
- Encouraging the development of a shared vision of science.

Secondly, the mapping process is being used within the project to track changes in teacher classroom practice over the project.

Supporting the change process: The SiS Strategy

The SiS Strategy refers to the process by which schools review their practice, and plan, implement, and monitor new initiatives, to improve their science teaching and learning within this project.

The Project has, from the start, been concerned to raise with schools fundamental issues of science teaching and learning, and to give ownership and responsibility for initiatives to the participating schools. The reason for this is twofold; a conviction that values and beliefs cannot be imposed but must be worked through carefully and over a period of time, and that teaching and learning strategies must be responsive to local school issues and cultures. This is not a curriculum project, nor is it a project concerned with promoting particular resources. The project can, however, draw on the considerable resources developed by DEET in the SiS projects in general, and sees itself as a broker and interpreter of the materials now available in Victoria under the SiS banner. These include the STEPS and ScienceTREK video and support materials, sample science programs, the Curriculum@work support materials, PRISM, an online resource of science learning sequences, and number of professional development initiatives, and a variety of partnership programs including scientists and engineers in schools, and family science.

During Phase 1 the development of a vision and the creation and implementation of individual school action plans was conceived of as the engine of change in the study schools. The original sequence of events and associated documentation in 2000 was based partly on the literatures dealing with science professional development, and whole school change (eg. Baird & Mitchell, 1986; Bell & Gilbert, 1996; Fullan, 1996; Hoban, 1997; Franke et al., 1998; Hall & Hord, 2001), partly on the teacher interviews, and also partly on the experience from other DEET initiatives such as the Middle Years Research and Development (MYRAD) Project (Hill & Crevola, 1999; Hill et al., 2000). Advice to schools has been successively refined using both verbal and written journal evidence concerning the procedures schools have followed, and which particular actions and processes have proved effective.

Figure 1 represents the current version of the planning phase of the SiS Strategy, leading to an Action Plan. This phase takes more or less all of first term in the school year. The main steps in developing the Action Plan are:

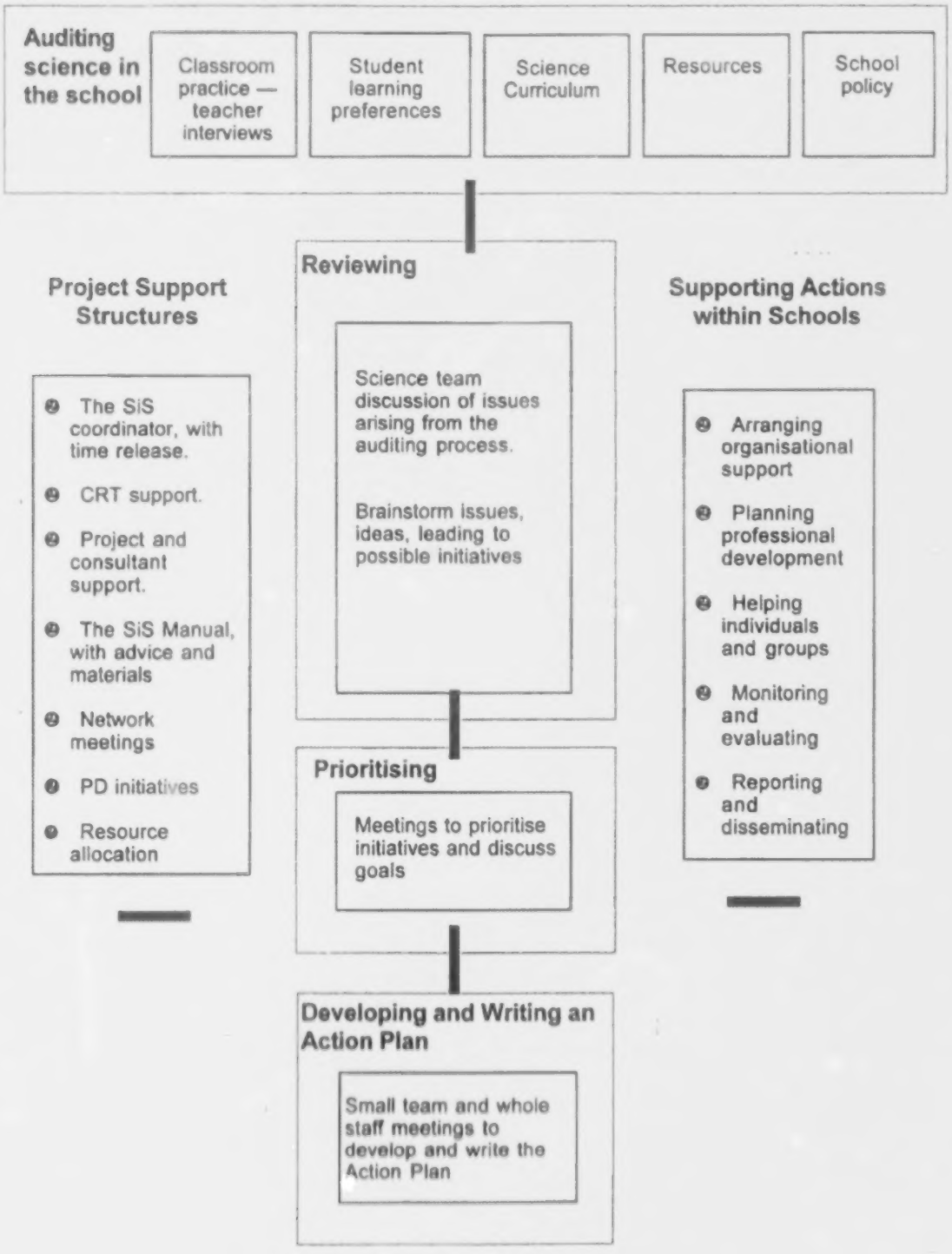
Auditing science in the school: A range of information deriving from student tests and surveys, teacher interviews and component maps, and analyses of school policies and resources;

Reviewing and Prioritising: Analysis of issues, and identification of goals and initiatives;

Developing and writing an Action Plan: The Action Plan specifies a range of actions to be taken at various times during the implementation process by the SiS Coordinator and teachers to ensure successful implementation of the SiS Components. It includes specific actions drawn from the Supporting Actions.

Detailed advice to schools concerning the implementation of the SiS Strategy, including a sequence of procedures, a variety of measuring instruments, examples of practice, and interpretive and analytical support documents, are contained in a comprehensive SiS Manual which schools are now using to guide their practice. This manual represents a major achievement for the project in encapsulating the lessons from the Phase 1 experience.

Figure 1: The SiS Strategy: Developing an Action Plan


Auditing science in the school
Classroom practice — teacher interviews
Student learning preferences
Science Curriculum
Resources
School policy
Reviewing
Science team discussion of issues arising from the auditing process.
Brainstorm issues, ideas, leading to possible initiatives
Prioritising
Meetings to prioritise initiatives and discuss goals
Developing and Writing an Action Plan
Small team and whole staff meetings to develop and write the Action Plan
Project Support Structures
The SiS coordinator, with time release.
CRT support.
Project and consultant support.
The SiS Manual, with advice and materials
Network meetings
PD initiatives
Resource allocation
Supporting Actions within Schools
Arranging organisational support
Planning professional development
Helping individuals and groups
Monitoring and evaluating
Reporting and disseminating

Outcomes of the first year

There is no doubt that considerable change took place in the Phase 1 schools during 2000, despite the short implementation period. This was evident in the number and range of initiatives that were undertaken, and the wealth of informal evidence concerning changes in classroom practice, curriculum change, and changes in the way staff related to each other and discussed teaching and learning issues.

Initiatives in schools

The circumstance of science in primary and secondary schools is very different in a number of respects; the background of teachers, the very different histories of curriculum provision and organisation, and different ways of arranging the curriculum. Consequently the project followed somewhat different pathways in primary and secondary schools.

Primary schools

The main problem facing primary schools in improving their science practice related to the lack of a strong tradition of science provision, and teacher confidence and knowledge concerning science and its teaching. The major focuses for primary schools were:

- In many primary schools science was inadequately represented in the formal curriculum. Consequently, the initial focus in most cases was a review of the curriculum against the Victorian Curriculum and Standards Framework (VBOS, 2000), and the writing of units. This resulted in increased science time, provided a vehicle for changing classroom practice, and embedded the SiS components into activity sequences.
- The encouragement of teachers to develop and trial activity based units, especially in the physical and chemical sciences, increasing teacher confidence and competence with science activities; and providing support for teachers through whole school professional development, shared planning, and in many cases, team teaching with the coordinator.
- The building up of science resources to support an activity based science curriculum, often in the form of unit boxes.
- Special initiatives such as family science nights or science clubs or camps undertaken to provide students with extended opportunities for learning and promote science in the school. In a number of cases this proved an effective vehicle for introducing staff to science activities and the enthusiasm they engender in children and parents.

Secondary schools

The main problems facing secondary schools proved to be (a) a tradition of formal teaching that often fails to engage students and cater for the range of responses to science, and (b) the lack of a tradition of joint curriculum planning and the sharing of ideas about teaching and learning. The major focuses for secondary schools were:

- establishing a tradition of team planning of units and the sharing of ideas concerning teaching and learning strategies.
- incorporating a wider range of teaching and learning strategies within existing science units.
- developing and trialling a range of teaching and learning strategies designed to better engage students and motivate them, to increase student autonomy through more open ended investigations and classroom discussions, and to cater more effectively for the range of abilities and interests.
- extending the use of the local environment in the science curriculum.

A comparison of initiatives in primary and secondary schools

The differences described above are reflected in the number of entries in the end of year reports concerning different types of initiative.

Type of initiative	% of instances in secondary school	% of instances in primary school

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	reports	reports
Classroom teaching and learning	43	20
Curriculum initiatives	16	20
Resource initiatives	11	27
Special initiatives	24	29
Transition initiatives	6	4

The transition initiatives tended to be strong in particular clusters, and mainly involved cross age tutoring but also some staff sharing of ideas and one example of a joint project.

Change in schools and teachers

In the end-of-year reports coordinators made various claims of ways teachers had developed their practice over the year, and evidence of changes in relation to teacher knowledge and beliefs, and science in the school. These specific claims were identified and collected using the NUD*IST text analysis software, and the categories describing these are listed below for primary and secondary schools. These findings are supported by informal evidence gathered by the project team and consultants. It is clear that there have been considerable gains made. The nature of changes, and evidence for it, include:

Primary schools

- A greater profile for science in the school itself, and the local community. This was particularly associated with the institution of events such as family science nights (or mornings);
- Science being instituted as a charter priority or at least a high priority area for 2001 in a number of schools;
- More time spent on science was claimed by many if not all schools. For many this was associated with science being more strongly represented in the integrated curriculum, but a number of schools put quantitative values on this in terms of time spent per week, or an increase in the number of science units in each year;
- A more coherent and thorough representation of science in the curriculum was a general underlying claim, which reflects the emphasis on curriculum auditing in the primary schools;
- Increased resources and access to resources, which encouraged an increase in hands on activities;
- Enthusiasm of the principal for the project was mentioned by a number of schools;
- Improved attitudes, particularly confidence, concerning science teaching. The evidence for this was mainly anecdotal;
- Some explicit mention of changes to the approach used in teaching science, such as an increased variety of activities, including open ended investigations;
- There were a number of reports of increased uptake of science by initially reluctant teachers, which will be produced as case studies. The change came about by either individual encouragement and support by the SiS coordinator, or the establishment of a group ethos of change that swept reluctant teachers along. Change was supported particularly by positive responses to new strategies by students.

The primary school reports focus more on confidence and a willingness to talk about science and incorporate it into their classroom practice, rather than refer to teacher change in terms of increased knowledge, or even very much about changing strategies. The focus is on increased quantity of science and its acceptance as a mainstream responsibility, and better planning for the teaching of science.

Secondary schools

- Substantial changes in teachers' use of a range of teaching and learning strategies consistent with the SiS components;
- Increased dialogue in meetings and in the staffroom about teaching and learning science;
- Greater willingness of staff to attend science PD;

- An increased sense of staff working together and recognising strengths and expertise of their colleagues;
- Increased profile of science in the school and community, associated again with special projects and the use of newsletters;
- In a number of schools there was recognition of the science KLA as leading the school in forging new approaches to teaching and learning and review of processes. As with primary schools, other KLAs were said to be using or planning to use the components in auditing and reforming their practice.

Secondary schools thus reported many similar instances of change to primary schools. There was a significant difference, however, in the focus on changes to classroom teaching strategies, compared to the focus on confidence and general competence for primary schools.

These different foci were confirmed by the self reporting of individual teachers in the component mapping exercise at the end of the year, concerning changes that had occurred in their classroom teaching practice, and also their perceptions of changes in science in the school. Their responses were categorised, taking care that no comments were lost, to yield a profile of change in secondary and primary schools. These are shown in Figures 2 and 3.

***Figure 2*: Primary and secondary teacher perceptions of change in science in the school**

(Put Figure 2 about here — see end of document)

Figure 3: **Primary and secondary teacher perceptions of change in classroom practice**

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Discussion and conclusion

The project has developed a set of descriptors of effective teaching and learning which have been validated against a broad range of literatures, have proved their worth in supporting schools in a process of significant change, and have captured the allegiance and imagination of teachers. One heartening finding, in developing the components, is that effective teaching and learning looks much the same in primary and secondary schools, and the project has opened up significant dialogue between primary and secondary teachers.

The specificity of the components have allowed their use in a component mapping process that has been valuable as a device for focusing attention on fundamental teaching and learning principles, and has demonstrated a clear shift in many teachers' classroom practice over the short time the project has been running.

The SiS Strategy — the process by which schools are supported to improve practice — allows considerable freedom for schools to adapt their focus to local needs and conditions. The different foci taken by primary and secondary schools has highlighted the science teaching and learning issues faced in each, due to the very different cultures operating. For primary schools the issues relate to confidence and competence to deal with practically based science, and the representation of science in a crowded curriculum. For secondary schools, the focus on teaching and learning strategies that enhance student engagement and cater more effectively for differences, highlights the challenge of the middle years of schooling and the well documented decline in student commitment to science across these years. Teacher perceptions of school change, and a wealth of qualitative data collected during the project, points to the general lack of serious discussion about teaching and learning in secondary school cultures, and the enthusiasm of teachers for the opportunity the project has provided for this.

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Figure 3: Primary and secondary teacher perceptions of change in classroom practice

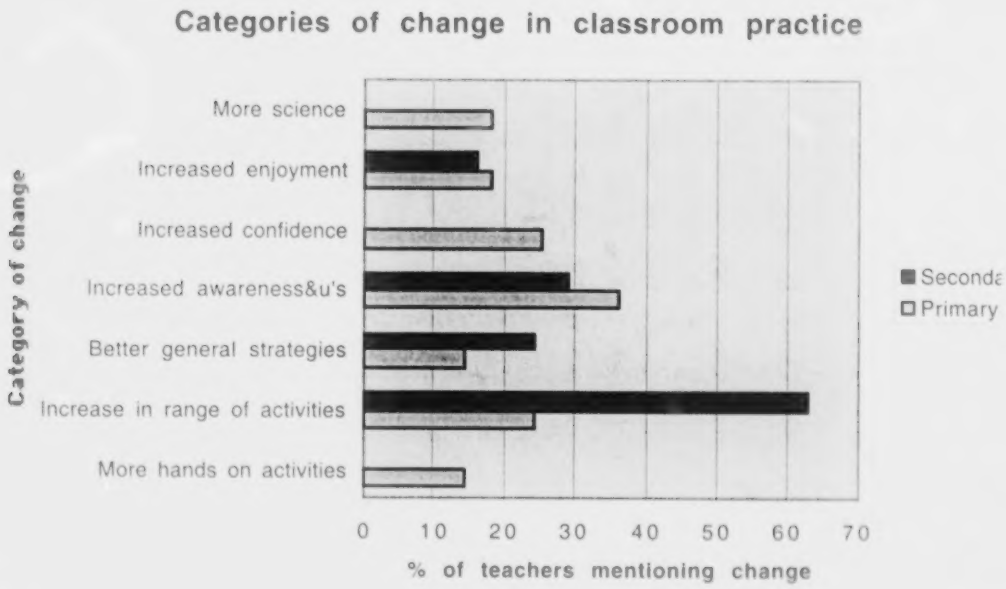

Figure 2: Primary and secondary teacher perceptions of change in science in the school